

## PARTIAL REPLACEMENT OF NONFAT MILK SOLIDS AND CANE SUGAR IN ICE CREAM WITH LACTOSE HYDROLYZED SWEET WHEY SOLIDS

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### ABSTRACT

Evaluation of vanilla-flavored ice creams that contained either 67 or 79% lactose hydrolyzed sweet whey solids (LHW) as a replacement for both milk solids nonfat (MSNF) and cane sugar showed that replacement of 2.75% of combined MSNF and cane sugar solids (13.6% of the total MSNF and 8.3% of the total cane sugar solids) with LHW can be made with no loss of ice cream quality. Increasing levels of LHW above 2.75% progressively lowered the quality of ice creams stored at  $-20^{\circ}\text{C}$ . Replacement with 5.5% of 67% LHW produced significant losses of flavor quality but did not change hedonic texture. Replacement with 5.5% of 79% LHW did not change either hedonic flavor or texture. Replacement with 8.25 and 11% LHW significantly decreased mix viscosities and freezing points, ice cream flavor scores (increased saltiness and caramel-like flavors) and consistencies although hedonic texture ratings were not always significantly lowered. Except for the 11% substitution of LHW for MSNF, ice creams had satisfactory heat shock stabilities.

### INTRODUCTION

CURRENT ICE CREAM standards permit replacement of up to 25% milk solids nonfat (MSNF) with unmodified whey solids. A change in the standards of identity for frozen desserts was proposed in 1978, permitting ice creams to be formulated from any milk derived ingredient with a minimum of 2.7% protein. This proposal stimulated research into the replacement of skim milk solids with caseins, wheys, and whey protein concentrates. Although this proposal was dropped, it is believed the results of these studies should be reported.

Frazeur (1967) showed that replacement of 25% MSNF with excellent-flavored dry whey in ice creams of 10.5–14.5% milk fat produced taste and texture scores equivalent to those of control ice creams. Steinholt (1974) reported that substitution of more than 40% of MSNF with whey solids produced lower flavor and melt down scores; 80% replacement produced a significantly lower score for consistency. Lowenstein et al. (1975) reported that up to 100% replacement with 50% lactase hydrolyzed neutralized cottage cheese whey for nonfat dry milk (NDM) produced ice creams of good body and texture, but 50 and 100% substitution gave poorer heat shock flavor and texture scores.

Bhursi et al. (1976) reported that neutralized acid whey can replace 25%, and this same whey with 80% of its lactose hydrolyzed can replace 40% of the MSNF in ice creams. Both unmodified and hydrolyzed sweet wheys can replace 60% of the MSNF in ice creams.

The objective of the present research was to develop acceptable ice creams exceeding a minimum of 2.7% protein when whey solids are used. It was thought this objective would best be achieved by replacing both MSNF and cane sugar with hydrolyzed lactose sweet whey solids (LHW) because (1) the literature reports that wheys containing hydrolyzed lactose produce better ice creams than

unmodified wheys, and (2) hydrolyzed lactose may be substituted for a portion of the cane sugar in ice creams (Guy et al., 1974). The lactose in sweet whey solids was hydrolyzed by lactase enzyme to either 67 or 79%; the notation used is LHW-A for the 67% hydrolyzed and LHW-B for the 79% hydrolyzed solids.

### MATERIALS & METHODS

#### Ingredients

Extra grade low heat NDM (Queen's Farm Dairy), Domino brand extra-fine grade granulated sugar, commercial pasteurized 40% fat-containing cream, 49% total solids (TS) hydrolyzed sweet whey concentrates, Kontrol brand (Germantown Manufacturing Co.) stabilizer-emulsifier, and McCormick onefold pure vanilla extract were used in ice cream mixes. Lehigh Valley sweet whey solids were used in mixes prepared for flavor evaluation by an expert panel of five judges.

#### Preparative methods

**HL sweet whey.** Maxilact brand (40,000 ONPG  $\mu\text{g}$ ) of *Saccharomyces lactis* lactase (either 0.8 g/gal of milk for HWS-A or 1.2 g/gal of milk for HWS-B) was added to raw whole milk held 16–18 hr at  $3^{\circ}\text{C}$ . The milks were pasteurized at  $71^{\circ}\text{C}$  for 15 sec, cheddar cheese was made, and the wheys were drained and pasteurized at  $63^{\circ}\text{C}$  for 30 min. The wheys were then clarified, and, after the fat was separated, cooled to  $4^{\circ}\text{C}$  overnight. The next day the wheys were concentrated to 49% TS in an APV evaporator and stored in plastic jugs at  $-20^{\circ}\text{C}$ .

**Ice creams.** Fifty pounds (22.7 kg) ice cream mixes were batch pasteurized for 30 min at  $74^{\circ}\text{C}$ , homogenized at 2000–500 psi (140–35  $\text{kg}/\text{cm}^2$ ) in a two-stage homogenizer, cooled on a plate exchanger to  $15^{\circ}\text{C}$ , and aged overnight at  $4^{\circ}\text{C}$ . Ice creams of 88–95% overruns were frozen in a 10-qt Emery Thompson batch freezer, then portioned into waxed 2-qt cartons, immediately placed in a hardening box at  $-30^{\circ}\text{C}$ , held overnight, and then transferred to a  $-20^{\circ}\text{C}$  storage cabinet.

#### Analytical methods

Total protein ( $\text{N} \times 6.38$ ) was determined by the micro-Kjeldahl procedure (AOAC, 1970), ash by the standard method for milk (AOAC, 1970), and total solids and fat by the Mojonnier procedures (Milk Industry Foundation, 1959). Degree of lactose hydrolysis was determined by the glucose-oxidase procedure (Jasewicz and Wasserman, 1961).

#### Ice cream mix evaluation

**Viscosity.** Duplicate apparent viscosities of ice creams at  $4.4^{\circ}\text{C}$  were determined by use of a Brookfield Sychroelectric Viscosimeter (#2 spindle, 60 rpm).

**Freezing time and temperature.** The freezing time and temperature are those required to obtain the proper stiffness of the mix as visually judged by an experienced operator. After freezing the ice cream mix, the refrigerant was turned off, the mix was whipped 1–1½ min to the desired overrun, and the ice cream was drawn from the freezer.

#### Ice cream evaluation methods

**Melting resistance.** Twelve centimeter diameter tea strainers containing 150–160g cut blocks of ice cream were suspended over large funnels, and the melted material was collected. Melt down was determined at  $37^{\circ}\text{C}$  as the weight percent of ice cream melted in 90 min.

**Overrun.** Overrun was computed from average net weights of 2-qt cartons of ice cream using a Pelauze Y-70 ice cream scale for reading overrun.

**Firmness.** Samples of ice cream mix were filled to the top of 4-oz plastic cups, placed in the hardening box overnight at  $-30^{\circ}\text{C}$ , and then transferred to the freezer boxes. Five-second penetration

Table 1—Analyses of milk-derived ingredients used in ice creams

Ingredient	Percentage			
	Moisture	Dry weight basis		
		Fat	Protein	Ash
Nonfat dry milk	4.4	1.28	37.0	8.3
67% lactose hydrolyzed sweet whey	48.9	0.78	13.1	6.9
79% lactose hydrolyzed sweet whey	49.3	0.66	12.5	8.0

Table 2—Formulation and analyses of ice creams containing, 12% fat, 0.28% stabilizer, and 0.5% vanilla

Percent				
Lactose hydrolyzed sweet whey solids	Milk solids nonfat	Cane sugar	Protein <sup>a</sup>	Ash <sup>a</sup>
0.00	11.0	15.0	4.1	0.9
2.75	9.5	13.75	3.9	1.0
5.50	8.0	12.50	3.6	1.1
8.25	6.5	11.25	3.4	1.2
11.00	5.0	10.00	3.2	1.3

<sup>a</sup> Calculated in mix containing 79% hydrolyzed whey

Table 3—Freezing characteristics of ice cream mixes containing lactose hydrolyzed sweet whey

Percent whey solids	67% Lactose hydrolyzed sweet whey			79% Lactose hydrolyzed sweet whey		
	Min freezing time	Freezing temp °C	Avg % overrun	Min freezing time	Freezing temp °C	Avg % overrun
0.00	8 3/4	-4.5	91	8	-4.5	94
2.75	8 3/4	-4.7	90	8 1/2	-5.0	87
5.50	9	-4.6	88	8 3/4	-5.3	95
8.25	9	-5.0	94	9	-5.6	91
11.00	9 1/2	-5.0	95	9 1/2	-6.0	94

values were obtained in triplicate by use of a Precision Scientific Penetrometer set up outside the freezer room. To minimize melting of the sample after being withdrawn from the freezer, one reading per sample was taken within an elapsed time of 15–20 sec.

**Heat shock.** Heat shock tests were made by removing 2-qt cartons of ice cream from the freezer (–18°C) twice daily and holding at 23–25°C for ½-hr periods over 5 consecutive days. The ice cream was returned to the freezer after each ½-hr period. Both heat shocked and nonheat shocked samples of each test formula were evaluated in triplicate against control NDM containing ice cream treated similarly.

**Panel evaluation.** Ice creams for panel evaluation were removed from the cartons, placed in 4-oz plastic cups, refrigerated at –18°C, and withdrawn for evaluation just prior to being tested. Taste and texture were evaluated on a 9-point hedonic preference scale (Peryam and Pilgrim, 1957) by a panel of 20–25 judges. The judges consisted of employees of ERRC who were trained in evaluating a variety of food products. Four samples were evaluated at each session, at least one being the control. Standard deviations measured on different days (between days) for nonheat shocked control NDM ice cream up to 1 month averaged ±0.23 for flavor scores and ±0.19 for texture scores, and for heat shocked ice creams, ±0.32 for flavor and ±0.40 for texture scores. Saltiness and sweetness were judged on a 7-point descriptive scale with the mid point of 0 designated as being just right, positive number 1 slightly, 2 moderately, and 3 excessively sweet or salty. Negative numbers were designated as 1 slightly lacking, 2 moderately lacking, and 3 excessively lacking in saltiness or sweetness. Iciness/coarseness scores were judged on a

Table 4—Analysis of ice cream mixes<sup>a</sup>

Percent whey solids	Percent lactose hydrolysis of added sweet whey					
	67			79		
	Percent total solids	Centipoise viscosity 4.4°C	pH	Percent total solids	Centipoise viscosity 4.4°C	pH
0.00	37.9	182a	6.59	37.7	183a	6.60
2.75	37.9	177ab	6.47	37.9	173ab	6.51
5.50	38.0	170ab	6.40	37.9	164bc	6.43
8.25	37.9	159c	6.39	38.2	162c	6.34
11.00	37.3	132d	6.31	38.4	141d	6.26

<sup>a</sup> Data followed by different letters are significantly different ( $P < 0.05$ ).

Table 5—Percent ice creams containing lactose hydrolyzed sweet whey solids melted in 90 min at 37°C<sup>a</sup>

Percent whey solids	Percent melted	
	67% Lactose hydrolyzed sweet whey	79% Lactose hydrolyzed sweet whey
0.00	38.8	42.3
2.75	44.0	44.7
5.50	45.2	44.1
8.25	45.2	42.8
11.00	46.3	44.2

<sup>a</sup> Differences nonsignificant ( $P > 0.05$ )

4-point scale of 0 = none, 1 = slight, 2 = moderate, and 3 = pronounced.

#### Statistical methods

All results on panel testing of ice creams were processed by the ERRC computer and analyzed by analysis of variance with Duncan's multiple range test used to determine significance of results. Significant differences of viscosities of mixes, melt down, and firmness of ice creams were analyzed statistically by use of the formula.

$$SD = \frac{2s\sqrt{a}}{\sqrt{n}}$$

where SD = significant difference; s = standard deviation; z = numerical rank apart in array of data; and n = number of replications.

The standard deviations for the above were evaluated from ranges, i.e., the difference between the largest and smallest measurements (Snedecor, 1959).

## RESULTS & DISCUSSION

THE MOISTURE, fat, protein, and ash analyses of the milk-derived ingredients are shown in Table 1. The formulations of ice cream and the calculated protein and ash contents of ice cream mixes containing LHW-B are shown in Table 2. The MSNF, sugar, and LHW in each ice cream totaled 26%. The protein and ash values in ice creams containing LHW-A varied slightly from those containing LHW-B because the wheys were from different milks. MSNF were calculated on a moisture-free basis from both the added NDM and serum solids of the cream (calculated as 5.4% of the weight of 40% fat cream). Small levels of fat contained in wheys and NDM were disregarded in calculations of the fat composition of the mix.

The use of 8.25% and 11% LHW slightly increased the time required to freeze the mix and slightly decreased the freezing temperatures (Table 3). This may be expected because of increased levels of salts and monosaccharides from

Table 6—Firmness of ice creams containing 79% lactose hydrolyzed sweet whey solids<sup>a</sup>

Percent whey solids	Average mm penetration in 5 sec		
	Lot 1	Lot 2	
	−21°C	−19°C	−14°C
0.00	8.9a	10.0a	12.2a
2.75	10.0b	11.5b	15.3b
5.50	11.4c	13.1c	16.4b
8.25	12.6d	15.1d	18.4c
11.00	13.7e	13.2c	16.3b

<sup>a</sup> Data followed by different letters in one column are significantly different ( $P < 0.01$ ).

LHW. Increasing LHW content progressively decreased mix viscosity and pH (Table 4). Replacement of MSNF and sugar with greater than 5.5% LHW significantly decreased mix viscosities.

Melt down times of all ice creams containing LHW were not significantly different from that of the control (Table 5). Firmness of two lots of ice creams decreased significantly with increased content of LHW-B (Table 6). An exception was the ice cream (Lot 2) containing 11% LHW, which might be explained by its somewhat lower overrun (86% vs 90–95%). The temperatures of −21° to −14°C approximate the temperature range of home freezers. The increasing softness of ice creams containing increasing levels of LHW and stored at −14°C was especially evident when portions of the ice creams were spooned and tasted.

Hedonic flavor scores of ice creams stored at −20°C containing LHW-A or -B, progressively decreased with increasing levels of LHW above 2.75% and to some extent with storage time (Fig. 1 and 2). For each storage period, average of duplicate values for the control NDM ice creams and single values of LHW samples were obtained for flavor and texture ratings. Ice creams with 5.5% LHW-A and 8.25% LHW-A or -B had significantly ( $P < 0.05$ ) lower flavor scores, and those containing 11% LHW-A or -B had very significantly ( $P < 0.01$ ) lower flavor scores than the control NDM ice cream. Flavor defects in ice creams with high levels of LHW were salty, caramel-like, or sirup flavor, and lacking vanilla. When evaluated by a panel consisting of five expert judges, mixes prepared in 400-g lots containing 11% either hydrolyzed or unmodified whey solids had caramel-like flavors. When the fat was omitted from a mix batch pasteurized at 74°C for 30 min or the complete mix was HTST pasteurized at 80°C for 25 sec, no caramel-like flavor was detected. Thus these flavors were judged to be formed by the result of heating milk fat and whey at batch pasteurization temperatures.

Increasing levels of LHW-A or -B progressively increased saltiness of ice creams (Fig. 3 and 4), which correlated with the increased ash of these mixes. Ice creams containing 2.75% LHW were not significantly different ( $P > 0.05$ ) from their controls. Those containing 5.5% LHW, on the average, were saltier ( $P < 0.05$ ) and those with higher levels of LHW were very significantly saltier ( $P < 0.01$ ) than the controls. Average saltiness scores of all ice creams containing LHW-A were lower than those containing similar levels of LHW-B, consistent with the lower ash (6.9%) of LHW-A. Even though the ice creams containing 11% LHW were rated saltiest, their scores averaged only close to slightly salty on the 4-point scale used.

Hedonic texture scores decreased slightly to moderately with increasing LHW (Fig. 5 and 6). Only the ice creams at the initial and 2-month storage period containing 11% LHW-B had lower texture scores ( $P < 0.05$ ). Although the panelists noted the softer body of the ice creams containing

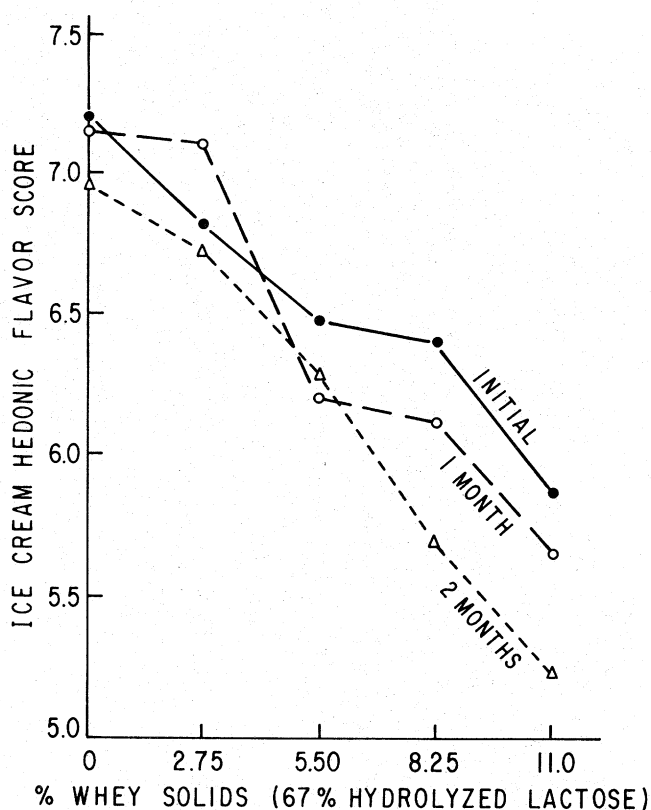


Fig. 1—Hedonic flavor scores of ice creams (LHW, 67%) stored at −20°C. All 5.5 and 8.25% LHW,  $P < 0.05$ ; all 11% LHW,  $P < 0.01$  from the control.

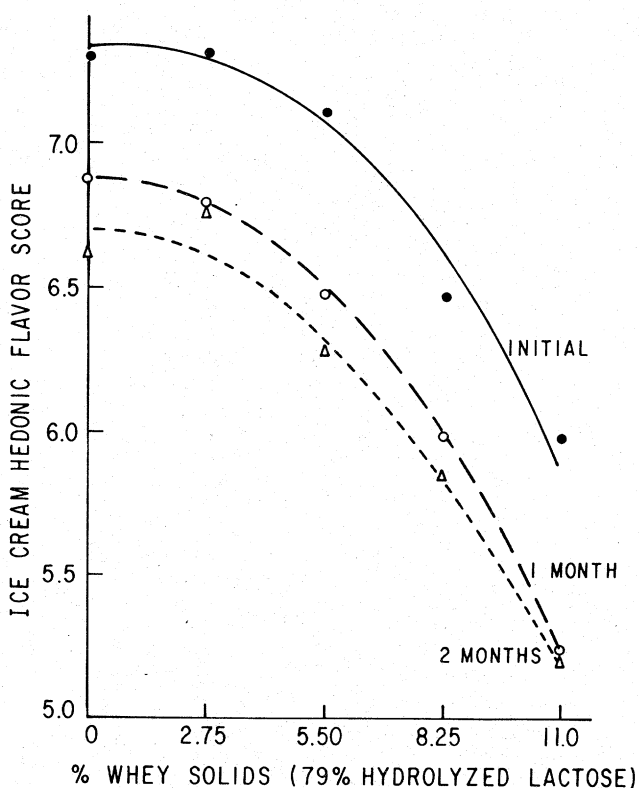


Fig. 2—Hedonic flavor scores of ice creams LHW, 79%) stored at −20°C. All 8.25 and 11% LHW,  $P < 0.05$  and  $P < 0.01$ , respectively, from the control.

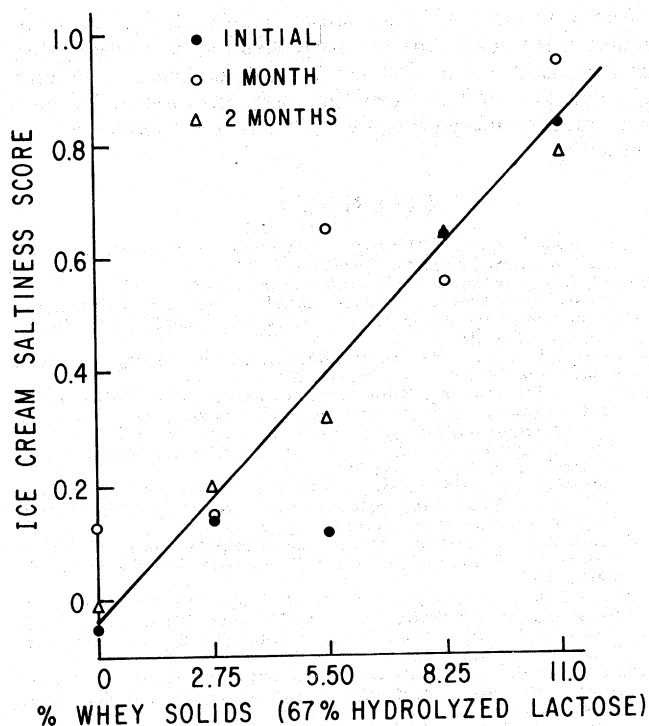


Fig. 3—Saltiness scores of ice creams (LHW, 67%) stored at  $-20^{\circ}\text{C}$ . 1 month, 5.5% LHW,  $P < 0.01$ ; 2 months, 5.5% LHW,  $P < 0.05$ ; all 8.25% and 11% LHW,  $P < 0.01$  from the control.

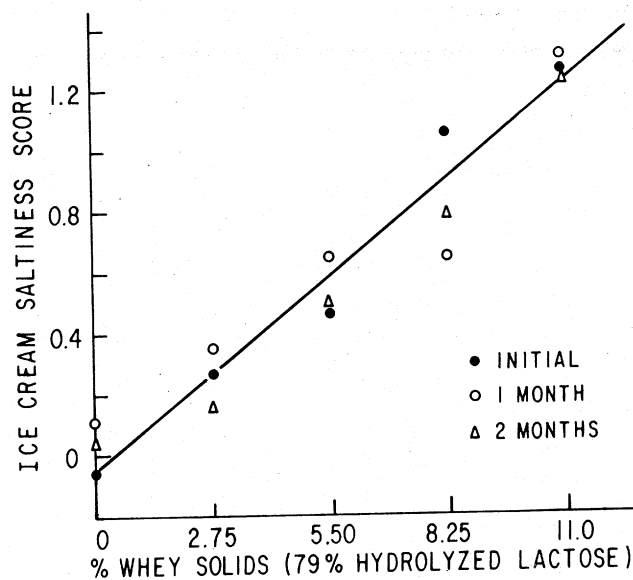


Fig. 4—Saltiness scores of ice creams (LHW, 79%) stored at  $-20^{\circ}\text{C}$ . All 5.5% LHW,  $P < 0.05$ ; all 8.25% and 11% LHW,  $P < 0.01$  from the control.

higher levels of LHW, they did not penalize this severely as a texture defect.

Sweetness scores of all ice creams averaged from 0.16–0.46 and showed no significant consistent pattern with respect to whey solids level, type used in the formulation, or time of storage. Neither did iciness/coarseness scores which averaged from 0.30–0.51. No sandiness was detected in any ice cream. Triplicate tests run on ice creams containing LHW-B showed that average texture scores de-

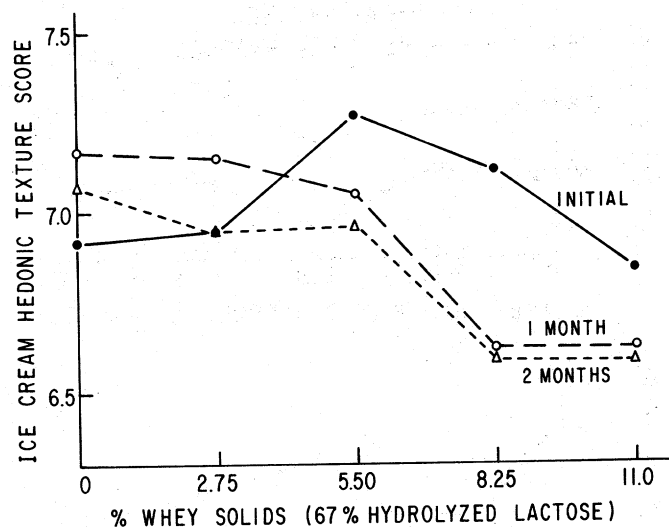


Fig. 5—Texture scores of ice creams (LHW, 67%) stored at  $-20^{\circ}\text{C}$ . All LHW,  $P > 0.05$  from control.

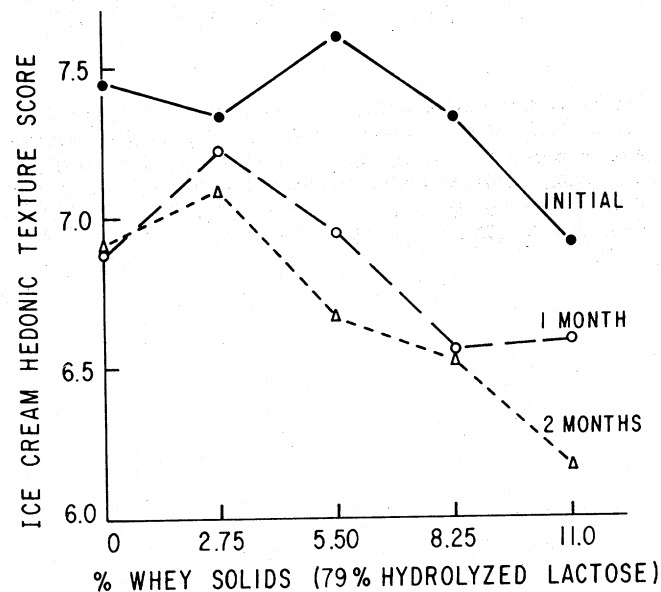


Fig. 6—Texture scores of ice creams (LHW, 79%) stored at  $-20^{\circ}\text{C}$ . Initial and 2 months, 11% LHW,  $P < 0.05$  from control.

creased (exception 2.75%) and coarseness scores of heat shock samples increased, although only the coarseness scores of 11% LHW were significantly higher in all three trials (Fig. 7). Heat shocking of the 12 controls on the average decreased texture and increased coarseness scores significantly in about a third of the samples and very little or not at all in the rest of the samples, indicating the possible variations that may be encountered in running these tests. Heat shocking was not any more deleterious to the LHW samples, with exception of the ice cream containing 11% LHW, than control samples. Heat shocking had no significant effect on the flavor score of any one sample.

## CONCLUSION

UP TO 13.6% replacement of milk solids nonfat and 8.3% sugar with lactose hydrolyzed sweet whey solids can be

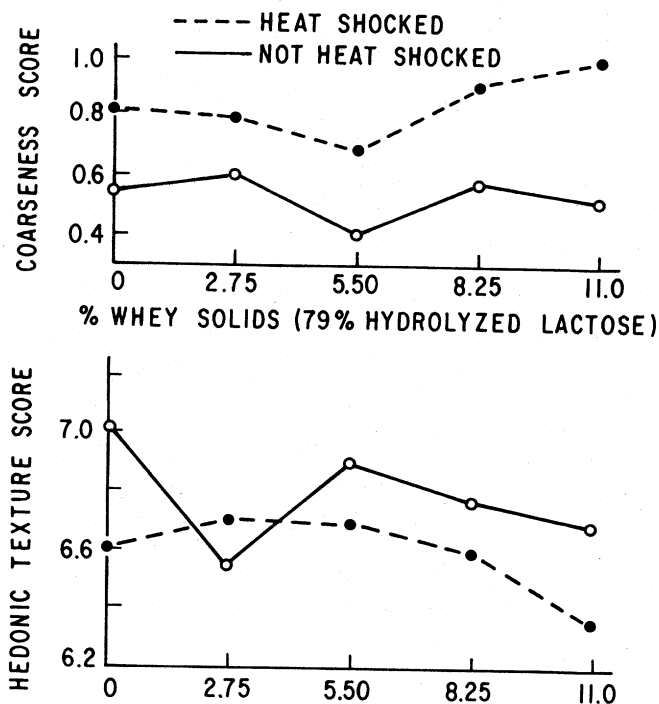


Fig. 7—Average texture and coarseness scores of heat shocked ice creams (LHW, 79%) compared to their respective controls. Texture: 9 NDM controls ( $P > 0.05$ ), 1 ( $P < 0.05$ ), 2 ( $P < 0.01$ ); 11% LHW, 2 ( $P > 0.05$ ), 1 ( $P < 0.05$ ). Coarseness: 7 NDM controls ( $P > 0.05$ ), 3 ( $P < 0.05$ ), 2 ( $P < 0.01$ ); 5.5% LHW, 2 ( $P > 0.05$ ), 1 ( $P < 0.05$ ); 8.25% LHW, 2 ( $P > 0.05$ ), 1 ( $P < 0.01$ ); 11% LHW, 1 ( $P < 0.05$ ), 2 ( $P < 0.01$ ).

made with no loss of ice cream quality. Higher levels of replacement contribute to progressive loss of flavor quality and consistency. Caramel-like flavor defect can be corrected by high temperature short time pasteurization of the mix, and saltiness most probably by partial demineralization of the whey.

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Reference to brand or firm names does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.